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Energy policy to promote photovoltaic generation

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ABSTRACT

Supplying present and future energy demand without adding to climate change is one of the most pressing problems today. Renewable energy is a potentially huge solution, for which governments are creating policies to encourage its harness and use. The dominance of photovoltaic (PV) among renewable energy technologies is owed mostly to its noiselessness, non-toxic emission, and relatively simple operation and maintenance. This study reviews the policies existing and in the making in seven leading countries that actively champion use of PV.

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Abbreviations: AUD, Australian Dollar; BIPV, building integrated PV systems; BMU, Federal Ministry for the Environment, Nature conservation and Nuclear; CAD, Canadian Dollar; CSH, concentrating solar high-temperature heat; CSP, concentrating solar power; DG, distributed generation; DOE, Department Of Energy; FIT, feed-in tariff; FY, Fiscal year; GDP, gross domestic product; GHG, green house gas; GWh, gigawatt-hour; IEA, International Energy Agency; ITC, Investment Tax Credit; JPEA, Japan Photovoltaic Energy Association; kWh, kilowatt-hour; LRET, large scale renewable energy target; MAFF, Ministry of Agriculture, Forestry and Fisheries of Japan; METI, Ministry of Economy Trade and Industry; MEXT, Ministry of Education, Culture, Sports, Science and Technology; MoE, Ministry of the Environment; MPPT, Maximum Power Point Tracking; MWh, megawatt-hour; NSSP, National Solar Schools Program; OPA, Ontario Power Authority; PGEP, photovoltaic generating electric power; PV, photovoltaic; PVPS, photovoltaic power system programme; REC, renewable energy certificate; RES, renewable energy source; RET, renewable energy target; RPS, renewable portfolio standard; REL, renewable energy law; SER, Syndicat des Energies Renouvelables; SETP, solar energy technologies program; SHCP, solar homes and communities plan; SPV, solar photovoltaic; SRES, small-scale renewable energy scheme

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1. Introduction

The ongoing process of climate change and the implications of this threat are one of the most challenging problems facing the world today [1]. The main reason for climate change is the greenhouse gases released from the burning of fossil fuels. Almost 80% of greenhouse gases come from production and consumption of energy. Globally and approximately, 40% of the average total energy consumption relate to buildings [2]. World primary energy demand will have increased almost 60% between 2002 and 2030; this is a 1.7% average annual increase, which further increases greenhouse gases [3]. Promoting electricity generation using renewable energy sources is one of the ways to overcome the global warming phenomena in the future. The energy source is sustainable, clean, and all-natural [4].

Nowadays, most countries are applying energy policy to promote electricity from renewable energy sources [5]. Among them, Germany, Japan, Spain, and the USA have contributed the most to PV market growth [6]. Energy policy is a strategy in which government decides to address the issues of energy development along with the development of the energy industry to sustain its growth; including energy production, distribution and consumption [7]. The main aim is to produce good-quality energy continuously and affordably within the principles of sustainable development [8].

Recent studies in the field of renewable energy sources have tackled diverse aspects of development and from different perspectives (e.g. legal, technical and economic) [4,9–14]. Most of these researches have emphasized on the application of two renewable resources; solar energy and wind. Among various solar energy technologies of sustainable energy sources, photovoltaic (PV) appears to be quite attractive for electricity generation because of its noiseless, non-carbon dioxide emission during operation, scale flexibility and rather simple operation and maintenance [15,16]. The International Energy Agency (IEA) estimates that solar power could provide as much as 11% of global electricity production in 2050 [16].

This paper will discuss various solar policies presently in place. Where most literatures discuss those of a specific country, this paper will look at the PV energy policies of the world and compare the energy policies of 7 countries. The review aims to aid researchers, policy makers, energy producers, and governments in their decisions and legislations [17].

2. Solar energy on the world

The mitigation of global climate change requires policies that encourage the production and use of renewable energy. It is often argued that such policies are best achieved via processes that involve many actors: not just bureaucrats and decision-makers, but also citizens, stakeholders, scientists, and other energy experts. If policy-makers rely only on the advice of one type of actor – e.g., energy producers – the legitimacy of the policy is diminished, and its implementation is hindered [18].

As we all know, there is basically only one source of energy for us, living on the Earth: the sun. The power it irradiates on our planet is estimated to be about 175,000 TW, four orders of magnitude more than the power we use even in our energy intensive times. The energy we have received and continue to receive from the sun is converted in many different ways by the dynamics of our planet and of its atmosphere: the high temperatures below the crust are due to its original activity; the presence of hydrocarbons in the soil, to ancient photosynthesis; winds and waves to the present thermal differences (Fig. 1).

Since 1994, worldwide solar PV market has experienced enormous growth (Fig. 2). According to a general overview of financial incentives in different parts of the world of PV systems among other technologies, incentives for PV systems have decreased over the last 10 years not only in the United States but also in major PV-based adopters such as The Netherlands, Austria, and Germany [19]. In fact, since 1994 the PV global market has increased by factor of 20. By end of 2007, the cumulative installed capacity of solar PV system reached 9200 MW, worldwide. About 6.2 GW of PV capacity were installed in the IEA PVPS countries during 2009 (much the same amount as in the previous year) which brought the cumulative installed capacity to 20.4 GW (Fig. 3). By far, the greatest proportion (74%) was installed in Germany and Italy

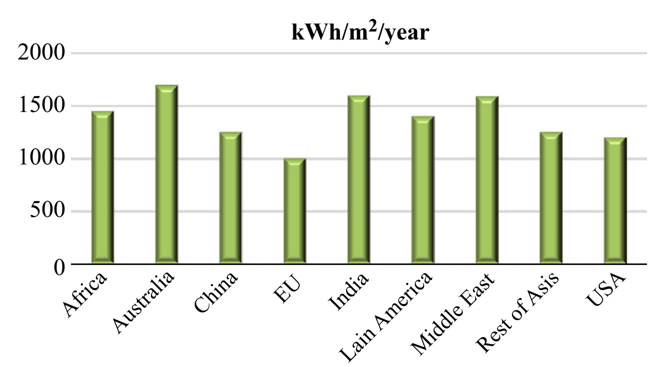


Fig. 1. Highest readings for sun radiation.

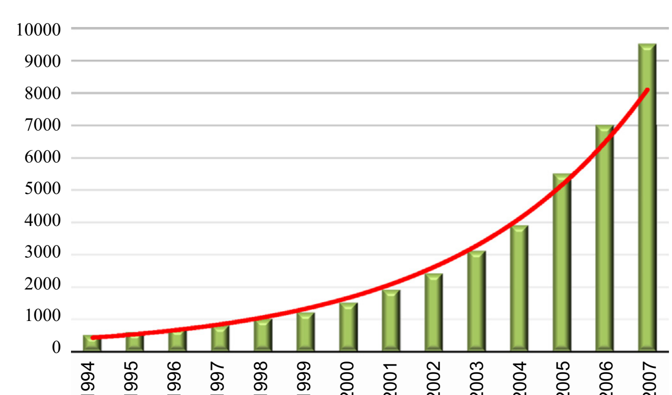


Fig. 2. Global cumulative installed PV capacity MW.

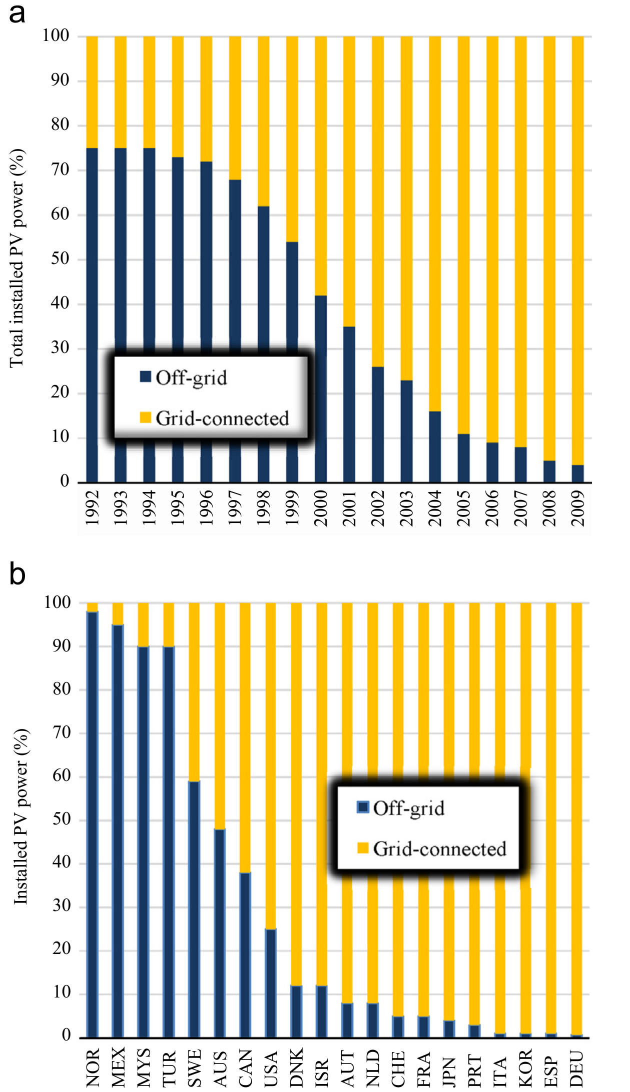


Fig. 3. (a) Percentage of grid connected and off-grid connected in the reporting countries, (b) installed PV power in the reporting countries by application (%) in 2009.

alone. If the US, Japan and France are also included, then over 93% of PV installations in 2009 occurred in five countries (Tables 1 and 2). Total PV capacity installed worldwide during 2009 was estimated to be a little over 7 GW [20]. The target set by the European Council requires that 20% of the final energy that we consume will be derived from renewable energy sources by 2020, and the photovoltaic market is continuing to expand without the quality of the installations being compromised [21].

- The Energy Scenario includes four different sources of solar energy:
- Solar power from photovoltaic (PV),
- Concentrating solar power (CSP),
- Concentrating solar high-temperature heat for industry (CSH),
- Solar thermal low-temperature heat for buildings.

PV is a well-established source of electric energy; around 21 GW of capacity installed worldwide at the end of 2009. The Scenario contains a potential for PV based on continuing annual growth rates of 25–30%, including outputs from both building-integrated and large area PV installations, for the next two decades [22].

As a result of concerns about climate change, the increase of the energy consumption rate, international agreements to reduce the GHGs emission and the availability of solar energy, governments worldwide are beginning to establish national goals for the provision of electricity from renewable energy and hence, trying to set-up the various solar energy policies in various countries.

Table 1
Forecasts for accumulative installed PV electricity generation capacity (GWp), as taken from the National Roadmap.

Year	2000	2010	2020	2030
United States	0.15	2.1	36	200
Europe	0.15	3.0	41	200
Japan	0.25	4.8	30	205
Word total	1.0	14.0	200	1850

Table 2
Forecast cost for PV electricity.

Year	2004	2010	2020
Japan (yen/kWh)	30	23	14
Europe (Euro/kWh)	0.25	0.18	0.10
United States (cents/kWh)	18.2	13.4	10.0

3. Review on solar energy policies for selected countries

A variety of policies like feed-in-tariff (FIT), renewable portfolio standard (RPS), investment tax credits (ITC), pricing laws, production incentives, quota requirements, trading systems etc., have been developed and implemented to promote the use of renewable energy [17,23]. These strategies have main objectives such as reducing the environmental impacts of the energy sector, reducing reliance on fossil fuels and encouraging new industrial development. The renewable portfolio standard (RPS) and the feed-in tariff (FIT) are the most popular policies until now. Although, there are a lot of debates surround their effectiveness of each one, expecting a choice that has to be made between them. For this, it could be decided by the countries that which RE policy can be applicable in their own particular circumstances and objectives. According to Ekins [24] "No optimal model has emerged, and probably none will do so in the contexts that is shaped by different histories and cultures".

3.1. Australia

The Australian Government has set an ambitious target that at least 20% of Australia's electricity needs will be met by Renewable Energy (RE) sources by 2020 (i.e. approximately 45,000 GWh of RE sourced electricity) in-line with its national plan for a clean energy future [25]. With some of the world's best solar and wind resources, Australia is a prime market for solar and wind energy [26]. Australia has only one flat-plate PV cell and module producer, Silex Solar, and they produced 8 MW of C–Si modules in 2010. Twenty-four coal power stations are the largest source of greenhouse gas emissions in Australia, pumping out 170 million tons of carbon dioxide (CO_2) every year. The pollution from these power stations is their main contribution to the problem of global warming. Coal is the main fuel for generating electricity in Australia – in 2000 84% of electricity came from burning coal, making Australia one of the top coal-burning countries in the world [27] (Fig. 4). The level of sun radiations in Australia is highest compared with other region (Fig. 1).

A total of 383 MW of PV was installed in Australia in 2010, a 480% increase over 2009. Of this, 99% was grid-connected, taking the cumulative grid-connected portion to 85%, up from 54% last

year. Total installed capacity in Australia is now 571 MW. The rapid increase in PV uptake has resulted in the curtailment or reduction of Government support programs and the market may over-correct in the short term [28]. Module prices averaged AUD 3.20/Wp but ranged from AUD 2.0 to 3.70 and small grid system prices averaged AUD 6/Wp, down from AUD 9/W last year.

The market for PV installations connected to central grids in Australia continues to increase and represented the largest market for PV in 2010 (Tables 3 and 4). The majority of installations took advantage of incentives under the Australian Government's Solar Homes and Communities Plan (SHCP) and Renewable Energy Target (RET) mechanisms, with further drivers provided by Feed-in Tariffs in some States and Territories. Grid-connected photovoltaic systems show a cost-effective policy for lowering electricity bills and reducing carbon emissions in Australia [29]. The main applications are rooftop systems for private residences. In June 2010, the 45,000 GWh Renewable Energy Target (RET) was separated into two parts, to commence on 1 January 2011 – the Large scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES). In December 2010 the Solar Credits multiplier for the 2011–2012 periods was reduced from 4 to 3, with multipliers in subsequent years also reduced by 1.

A summary of the cumulative installed PV power, from 1992–2010, broken down into five sub-markets are shown in Table 5 and Fig. 5.

More than 79 MW of PV were installed in Australia in 2009, three and a half times the amount installed in 2008 (Fig. 6). Of this nearly 87% were grid-connected, taking the cumulative grid-connected portion to nearly 55% up from 30% in 2008 (Figs. 7 and 8). Total installed capacity in Australia reached 183.6 MW [20].

The Australian Government has expanded the Renewable Energy Target (RET) to 45,000 GWh by 2020. The RET will continue to use the Renewable Energy Certificate (REC) mechanism, with each MWh of renewable energy generation eligible for one REC. REC multipliers, or Solar Credits, are available to PV systems, wind turbines and micro-hydro systems for the first 1.5 kW of capacity. As well as home-owners, organizations such as schools, community groups, businesses and developers are eligible for Solar Credits, and no means test will be applied [20].

The 480 million AUD National Solar Schools Program (NSSP) commenced on 1 July 2008 and finishes on 30 June 2015. NSSP offers primary and secondary schools grants of up to AUD 50,000 to install solar and other renewable power systems, solar hot water systems, rainwater tanks and a range of energy efficiency

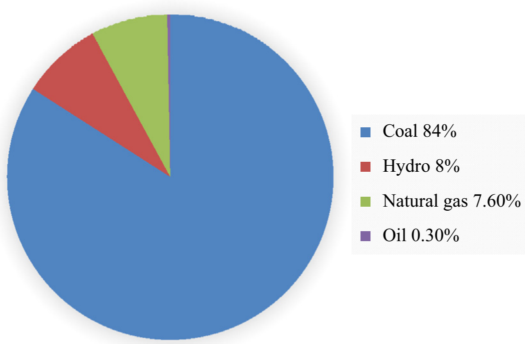


Fig. 4. Australia's level of dependence on coal-based electricity [27].

Table 3
2010 figures for PV power installed in 4 Australian sub-markets [28].

Submarket/ application	Off-grid domestic	Off-grid non-domestic	Grid-connected distributed	Grid-connected centralized	Total
PV power installed in 2010 (MWp)	3.5	0.4	378.2	1.3	383.3

Table 4
PV power and the broader Australian electricity market [28]

Total Australian PV capacity as a % of total national electricity generation capacity	New(2010) PV capacity as a % of new electricity generation capacity	Total PV electricity production as a % of total electricity consumption
1	20	0.3

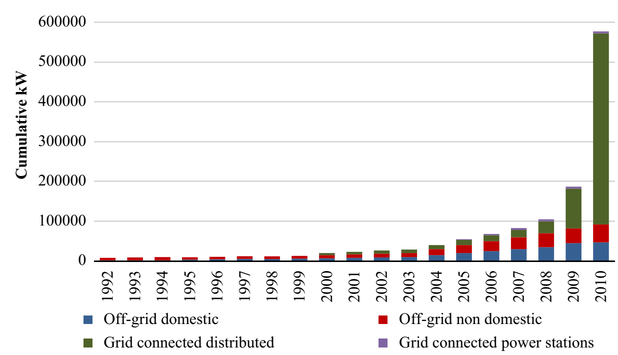


Fig. 5. 1992–2010 Cumulative PV installation (MW) in Australia [28].

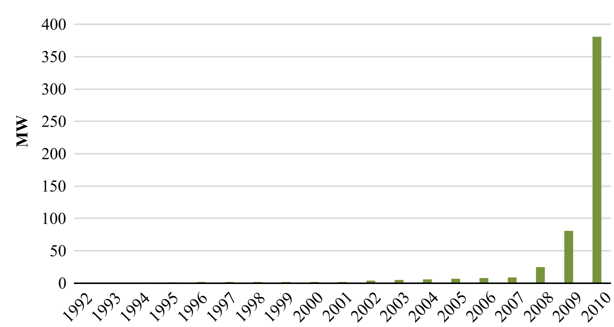


Fig. 6. 1992–2010 Annual PV installation (MW) in Australia [28].

Table 5
The cumulative installed PV power in Australia across 4 sub-markets [28].

Submarket	1992	1993	1994	1995	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Off-grid domestic	1.56	2.03	2.6	3.27	4.08	4.97	6.07	6.93	9.22	11.07	12.45	14.28	16.59	19.89	23.88	27.71	32.68	40.76	44.23
Off-grid non-domestic	5.76	6.87	8.08	9.38	11.52	13.32	15.08	16.36	17.06	19.17	22.74	26.06	29.64	33.07	36.65	38.73	40.66	43.14	43.57
Grid connected distributed	–	0.01	0.02	0.03	0.08	0.20	0.85	1.49	2.39	2.80	3.40	4.63	5.41	6.86	9.01	15.04	29.85	101.21	479.34
Grid connected centralized	–	–	–	0.02	0.20	0.21	0.52	0.54	0.54	0.54	0.54	0.66	0.66	0.76	0.76	1.01	1.32	2.53	3.79
Total (MWp)	7.30	8.90	10.70	12.70	15.70	18.70	22.52	25.32	29.21	33.58	39.13	45.63	52.3	60.58	70.30	82.49	104.5	187.64	570.93

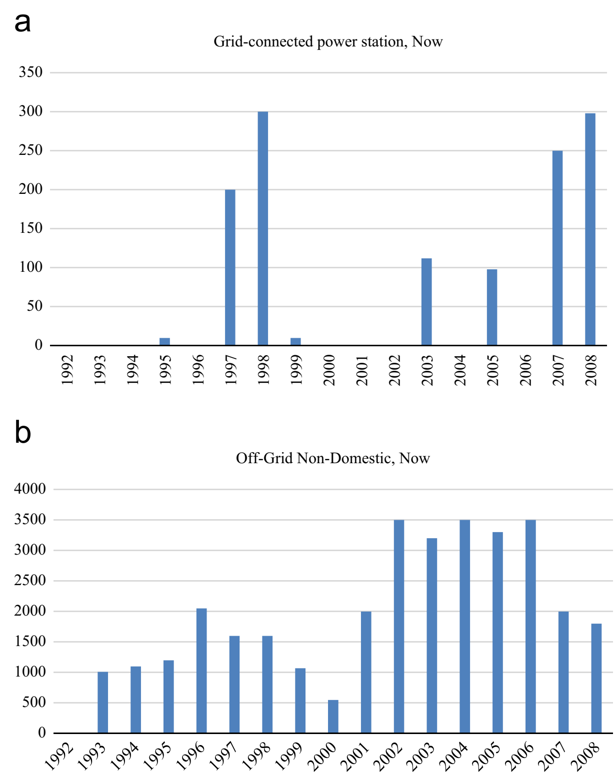


Fig. 7. Australia (a) New installation of grid connected power station. (b) New installation of off-grid non-domestic PV [26].

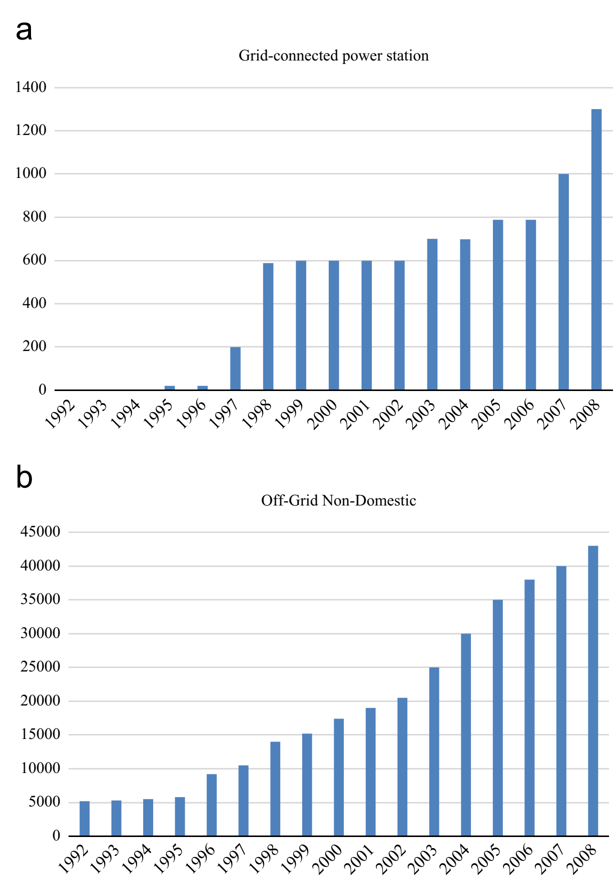


Fig. 8. Australia (a) cumulative installation of grid connected power station. (b) Cumulative installation of off-grid non-domestic PV [26].

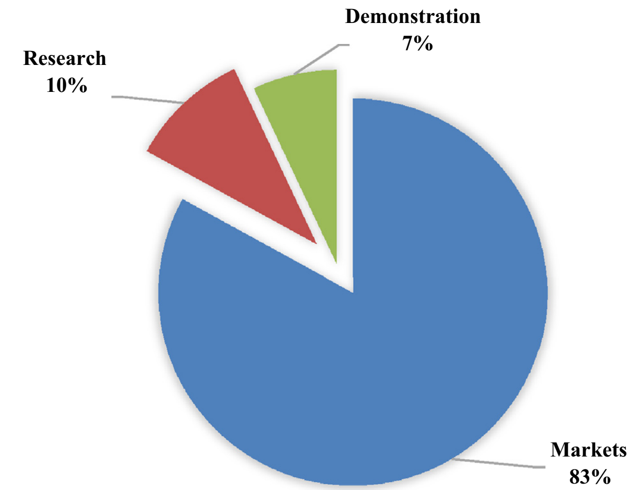


Fig. 9. 2010 allocation of Australian Commonwealth and state government budget for PV R&D demonstration and market [28].

measures including insulation, energy efficient lighting and ceiling fans. To May 2010, funding totaling more than 114 million AUD had been paid or approved to more than 2500 schools. In addition, over 1000 schools have reported their installations complete. The Australian grid-connected PV market grew significantly in 2009, due to the rebates available through the Solar Homes and Communities Plan, and then through the Solar Credits Renewable Energy.

Certificate multiplier, operating as the part of the RET, state based feed-in tariffs, schools programs and other support activities have ensured a strong market, which continues through 2010. The off-grid market, previously Australia's main PV market, no longer has any specific program support, with the ending of the Renewable Remote Power Generation Program during 2009. Australia no longer has a local PV manufacturer; however Australian Government plans to encourage large-scale PV systems through a Solar Flagships Program has increased international interest in the potential for companies to begin cell or module manufacture in the future [20] (Fig. 9).

3.2. Canada

Canada's total PV power installed capacity reached 94.57 MW in 2009 compared to 32.72 MW at the end of 2008 (Table 6). The grid-connected market now accounts for 87% of the market in 2009 compared to only 33% in 2008. This is a significant growth sector that is spurred by the new province of Ontario's feed in tariff launched in 2006 and expanded in 2009. The grid connected applications included 11% for residential and building integrated applications, and 76% for three large ground-mounted utility scale systems. The off-grid applications are not subsidized and only represented 13% of PV systems installed in Canada in 2009. This consists of stand-alone applications comprising a PV array as the sole generator or as a hybrid system combined with a small wind turbine or diesel generator. The installed price for systems range between CAD 6000 and 8000 per kilowatt for grid-connected installations, and CAD 16,000 per kilowatt for off-grid systems that include storage. Total public budgets in Canada significantly increased to $31.2 million CAD which is an increase of over 315% due to the market incentive program in the province of Ontario [30] (Tables 7-9).

The installed off-grid power capacity in 2009 was 7.71 MW compared to 54.14 MW for the grid-connected market (Table 10). This is a significant transition for the PV industry that historically

Table 6
2009 cumulative installed PV power (MW) in 4 Canadian sub-markets [30].

Submarket	1992	1993	1994	1995	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Off-grid domestic	0.1	0.19	0 31	0.45	0.51	0.86	1.38	2.15	2.54	3.32	3.85	4.54	5.29	5.9	6.68	8.09	10.6	15.19
Off-grid non-domestic	0.69	0.84	0.99	1.19	1.7	2.26	2.82	3.38	4.3	5.16	5.78	6.89	8.08	9.72	12.3	14.77	16.88	20.01
Grid connected distributed	0.17	0.19	0.2	0.21	0.24	0.25	0.26	0.29	0.3	0.34	0.37	0.4	0.47	1.07	1.44	2.85	5.17	12.25
Grid connected centralized	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0.04	0.06	0.06	0.06	0.06	47.12
Total (MWp)	0.96	1.23	1.51	1.86	2.56	3.38	4.47	5.83	7.15	8.83	10	11.83	13.88	16.75	20.48	25.77	32.72	94.57
Total off-grid	0.79	1.03	1.3	1.64	2.31	3.12	4.2	5.53	6.84	8.48	9.63	11.43	13.37	15.62	18.98	22.86	27.48	35.2

Table 7
Trends in public budgets for R&D, demonstration/field test programmes and market incentives in Canada in 2009 (Million CAD) [30].

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total combined (Federal, provincial)	0.89	1.5	1.95	5.96	8.54	9.8	7.7	8.15	10.4	7.51	31.2
Annual trends	–	68%	30%	205%	43%	15%	-21%	6%	28%	–28%	315%

Table 8
Trends in total PV labor places in Canada for 1996–2009 [30]

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Total labor	169	201	220	250	260	275	535	615	765	975	1080	1370	2080	2700
Annual growth	–	19%	10%	14%	4%	6%	94%	15%	24%	27%	11%	21%	53%	30%

Table 9
Public budget for R&D demonstration/field test programs and market incentives in Canada in 2009 (Million CAD) [30].

	R&D	Demo/field test	Market incentives	Total
Federal	2.6	1	0	3.6
Total	3.6	1.6	26	31.2

Table 10
2009 PV power (MW) installed in 4 Canadian sub-markets [30].

Sub-marked application	Off-grid domestic	Off-grid non-domestic	Grid-connected distributed	Grid-connected centralize	Total
PV power n installed	4.58	3.13	7.08	47.06	61.85

Table 11
Ontario power authority feed-in tariff for solar PV.

	Application type	Size	Contract price (c/kWh)
MicroFIT	Rooftop	< 10 kW	80.4
FIT	Ground-mounted	< 10 kW	64.2
	Rooftop	10–250	71.3
	Rooftop	250–500	63.5
	Rooftop	> 500	53.9
	Ground-mounted	10 kW–10 MW	44.3

Table 12
Summary of progress of the Ontario FIT program.

FIT	Application	Awaiting ECT	Offered contract	Executed contract
Number	3656	72	1376	1119
Capacity (MW)	4886	592	911	856

served mainly the off-grid market. The subsidies provided by the Ontario Power Authority (OPA) for both rooftop and ground mounted photovoltaic installation led to a huge market increase of 791% in Canada in 2009.

In 2010, the world's largest solar-PV facility was built by the Enbridge and first solar 80 MW Sarnia solar project in Ontario. Ontario's FIT program, managed by the OPA, is North America's first comprehensive guaranteed pricing structure for electricity production from renewable fuels sources including solar-PV, bio energy, waterpower and wind. The incentive program is divided into two streams, one targets the small, medium and large renewable energy projects generating more that 10 kW of electricity (referred as the "FIT Program"), and the other targets very small renewable projects generating 10 kW of electricity or less, such as home or small business installations (referred to as the "microFIT Program"). Prices paid for renewable energy generation under FIT and microFIT programs vary by energy source and take into account the capital investment required to implement the project (Table 11). Under the program, solar PV enter into a 20 year contract to receive a fixed price of up to CAD 0.802 per kWh for the electricity they generate [21].

As of December 2010, the OPA received, under the FIT program, 3656 applications representing about 4886 MW of PV generating capacity (Table 12). Under the microFIT program, the OPA received 18,176 applications representing 166 MW of generating capacity (99% of which was for PV) (Table 13) [31].

Table 13
Summary of progress of the Ontario microFIT program.

MicroFIT	Approved	Executed
Number	18,176	2619
Capacity (MW)	166	21

3.3. China

China is the world's most populous country with over 1.3 billion people. It has experienced tremendous economic growth over the last three decades with an annual average increase in gross domestic product of 9.8% during that period. This growth has had huge implications for energy consumption and environmental impact [32]. This has led to an increasing demand for energy, spurring China to add an average of 53 GW of electric capacity each year over the last ten years to its power generation capabilities. It is obvious that most of the Chinese electricity generating capacity is based on coal fired power stations [33]. China's carbon emissions are low on a per capita basis; China is already ranked the world's second largest producer of carbon emission, behind only America [17]. At the same time, approaching 50% of China's oil consumption comes from the overseas market, causing a significant energy supply security concerns [34].

China has set ambitious targets for developing its non-hydropower renewable energy resources with a major push of laws, policies, and incentives in the last few years [35]. Among the technologies referring to utilization of solar energy, concentrating solar power (CSP) is a promising option, which has a profound significance for China, but in comparison, Solar photovoltaic (SPV) technologies are more mature than solar thermal power generation technologies. Therefore, solar power is definitely an important CO_2 mitigation option at the present and in the long-term. The China government has provided a fund to support solar energy demonstration projects. This fund is for solar technologies that provides heat and electricity. In March 2009, the Ministry of Finance and MOHURD made available a subsidy specifically targeting the use of photovoltaic on buildings. The subsidy is 20 RMB/watt peak (Wp) (2.9 USD/Wp), which will cover nearly half of the investment [36]. China's solar cell has experienced rapidly growth inspirited the booming of German PV market. The total output of China's solar cell in 2007 was 1088 MW, ranking it first in the world [37]. Although China is a top manufacturer of solar panels, the high cost of the most efficient technologies hinders their deployment. By the end of 2007, the total installed capacity of photovoltaic power generation was about 105 MW, and the new PV capacity 25 MW. Namely, more than 90% of China's solar cell exports to overseas [38].

3.3.1. Photovoltaic development

The potential of solar energy in China is very high. Recently, it has been found that the special considerations on solar power have effectively decreased the cost of photovoltaic (PV) power generation. For instance, in 2007, electricity tariff from PV generation was 4 Yuan (US Cent 58.9)/kWh. In 2008, Sun tech Power Co. Ltd., the biggest Chinese solar cell producers, declared that it can reduce the PV power price to 1 Yuan (US$ 0.15)/kWh by 2012. Moreover, in 2009 the PV concession demonstration project has propelled the PV generation to reduce to 0.69 Yuan (US$ Cent 0.1)/kWh. The continuous pressure for carbon reduction has tempted China to determine its future energy policies. The market share of Chinese PV has increased from 1% to 35% in the last 8 years, and the quality has step up at the same time. According to the data of Germany web news, the total yield of Chinese solar cell in 2007 is more than 1200 MW, which have a share of 35% in whole world, which ranks the first in the world. Based on the news of economy daily, the total yield is more than 2000 MW in 2008 [37,39]. A similar goal exists (China has set a goal) for the solar photovoltaic (PV) power sector which China intends to increase capacity from 140 MW as of 2009 to over 1.8 GW by 2020. With the great potential of solar resources, China is getting more serious about the large-scale utilization of solar power because of its booming production capacity of photovoltaic industry [40]. At present, the PV market in China is mostly used to the electric energy supply of remote villages and communication and solar energy manufacture and PV generating electric power (PGEP). Some productions are used to improve the daily life of common people, such as solar energy street lamp, solar energy lawn lamp, solar energy traffic signal lamp and solar energy sight lighting. The grid-connect energy production is located in demonstration moment due to the costly price of PV generating electric power. According to the present plan, total PV power installations will reach 300 MWp by 2010, 1.8 GWp by 2020 and 1000 GWp by 2050. According to forecasts made by the Chinese Electric Power Research Institute, renewable energy installations will account for 30% of total electric power capacity in China by 2050, of which PV installations will account for 5%. At present, the biggest photovoltaic plant is established in Shilin of Yunnan province. The capacity and the investment are 66 MW and 0.6 billion dollars, respectively. Consequently, the market and development potential of solar energy are startling in the future China [41]. At present, more and more Chinese enterprisers begin to invest the PV industry. Certainly, the PV industry of China faces some difficulties at present, such as the technology of production, raw and processed materials and environmental pollution.

3.3.2. Solar energy policies

In 2005, the National People's Congress has passed The Renewable Energy Law (REL) [42]. This law has marked a new stage of renewable energy development program in China. Since the introduction of REL, a number of supporting regulations and guide-lines have been put into place to implement it. The law was designed to “promote the development and utilization of renewable energy, improve the energy structure, diversify energy supplies, safeguard energy security, protect the environment, and realize the sustainable development of the economy and society.” China's initial goal for solar power was established in 2007 at a modest 1.8 GW, but this target is in the process of being revised upward to perhaps 20 GW. A “Golden Roofs” initiative announced in March 2009 provides a subsidy of $2.93 per watt for roof-mounted PV systems over 50 kW (kW) which could cover over half of a system's installation cost. A feed-in tariff of $0.16 per kilowatt-hour (kWh) was also established for PV power projects at the same time. Encouragement for larger utility scale solar projects was announced in July 2009 under the “Golden Sun” program, which provides up to 50% of project costs (including transmission or distribution lines to connect to the grid), and up to 70% of such costs for projects in more remote areas (such as the Western Region). The Golden Sun program is for projects of 300 MW capacities and above, which are in service for a minimum of 20 years.

Although the history of renewable energy development in China is short, the Chinese government has formulated and executed a series of policies and specific policy measures for the purpose of renewable energy development [43]. These policies include:

(i) All PV electric power should be purchased by power company, and which should provide enough grid-connect service.

(ii) The electrovalence is established more than conventional price in order to encourage the development of solar energy, the benefits of investor should be ensured.
(iii) The central government gives some allowances to the renewable resources industry.
(iv) The central government encourages the renewable resources DG (distributed generation) in order to improve the electric power serves of no electric power supply region, and the early investment and medium-term maintenance are afforded by central government.
(v) Although the end user uses the electric power from PV generation, but the electrovalence of end user is same compared with the end user who uses the conventional electric power.

As mentioned above, the central government of China regards the development of PV in order to improve the unreasonable energy structure. Policies for encouraging renewable energy in China are largely driven by the central government, and enacted through national and provincial and local government programs. China led the world in 2009 in renewable energy investment, spending $34.6 billion, with the United States second in clean energy spending, investing $18.6 billion [44]. Financial support for renewable energy in China involves subsidies, tax policies, pricing mechanisms, and a reward scheme for green production. Subsidy support is extended to overhead costs of programs (i.e., administrative, operational, and other expenses for government renewable energy agencies), renewable energy technology research and development, and provincial or local electrification projects. Tax incentives can come from the central or local governments, and can be technology specific. Pricing for renewable energy is not standardized, and is set by contracts negotiated between projects and utilities.

Despite of these programs the renewable energy economy is not yet cost-competitive with the fossil energy economy. Hence the continued development of the renewable energy economy is dependent upon government support. Examples of such support include economic encouragement policy (e.g., financial subsidy, favorable taxation policy, and favorable price policy), industrialized support policy, technical research and development policy, and government renewable resources model projects. However, As Chen [45] noted that much more could be done to support policies for renewable energy development in China. As Lisheng and Xinrong [46] conclude, for example, there is lack of co-ordination and consistency in policy, weak and incomplete encouragement system, no innovation in regional policy, incomplete financing system for renewable energy projects, and inadequate investment in the technical research and development for renewable energy. In order to improve the inopportune energy structure and sustainable development the Chinese central government has established some policies and laws, in this regard the following measures were especially recommended

(i) The applications of solar energy are promoted by the policy of central government and local governments, the allowance of government is important to increase the competitive power of PV production. And the Chinese central and local government should increase the research fund of PV to grasp the pivotal technology, such as circuit topology and MPPT (maximum power point tracking) control method and grid-connect. Moreover, there should be tax reduction or exemption by government, which will motivate the enthusiasm of entrepreneurs, and which will increase the PV market through government policy initiatives. The advantage of investors should be ensured by government policies. Certainly, the government fund should be launched in the vast power supply project in order to improve the energy structure in the foreseeable future. For example the large desert grid-connected power plant must be established. The ordinary investor and corporation cannot supply the vast fund in the desert grid-connected power plant domain. The devotion of government is obligatory.
(ii) Abundant fund and personnel should be launched into the interrelated research of PV, and the universities and graduate schools should be encouraged to research in solar energy. The cooperation between corporations and universities should be enhanced in order to improve the research level. The students are trained by universities in order to supply enough persons with ability to cooperation. Certainly, international cooperation should be encouraged to improve the domestic technology by central government and local governments.
(iii) The PV industry chain should be established in order to enhance the economy benefit of Chinese PV industry. Especially, the lack of silicon material and pivotal technology should be settled in future. The PV market should be enlarged in order to digest large numbers of PV product. The attestation and detect organization lacks the contact with the international organization, and the criterion of whole industry should be established.

3.4. Japan

The Japanese electricity sector is facing serious challenges in the aftermath of the Fukushima nuclear disaster. The government has responded to the crisis with a new feed-in-tariff to promote increased utilization of renewable energy, and proposed to reduce the dependence on nuclear power [47]. The Japanese PV system market is dominated by grid-connected distributed PV systems, mainly for private housings, collective housings or apartment buildings, public facilities, industrial and commercial facilities, and buildings [48]. The PV market development has been driven by residential PV systems with a capacity of 3–5 kW, as well as PV systems with a capacity of 10–1000 kW for public facilities, industrial and commercial facilities, and buildings. Residential PV systems account for 81.4% of grid-connected market in Japan, leading Japan's grid-connected distributed PV system market [49].

The off-grid domestic PV system market is small in size, and mainly for residences in remote areas including mountain lodges and huts, isolated islands and some public and industrial facilities. The off-grid non-residential PV system market mainly consists of street lights, power source for telecommunications, power source for observatory facilities, pumps, disaster prevention, agricultural application, road and traffic signs and ventilating fans. Off-grid non-residential market has already established an independent market requiring no subsidies.

Total installed capacity in 2010 was 990,979 kW, and the annual installed capacity for each application is as follows: 739 kW for off-grid domestic PV systems, 3422 kW for off-grid non-domestic PV systems and 986,818 kW for grid-connected distributed PV systems mainly for residential houses (Table 14).

Table 14
2010 Installed PV power in 4 sub-markets in Japan [49].

Sub-market/ application	Off-grid domestic (kW)	Off-grid non-domestic (kW)	Grid-connected distributed (kW)	Grid-connected centralized (kW)	Total (kW)
Installed PV power	739	3422	974,225	12,593	990,979

In addition, 12,593 kW was installed for large-scale grid-connected centralized PV power application by utilities and local authorities.

Table 15 shows cumulative installed capacity of PV systems by submarket. In 2010, total cumulative installed capacity was 3,618,144 kW. Cumulative installed capacity for each application is as follows: 3374 kW for off-grid domestic, 95,420 kW for off-grid non-domestic, 3,496,017 kW for grid-connected distributed and 23,333 kW for grid-connected centralized application.

The Ministry of Economy, Trade and Industry (METI) resumed the Subsidy for Installation of Residential Photovoltaic Systems in 2009 and that subsidy program was continued in 2010 (Table 16). In addition, since the government introduced a new scheme to oblige electric utilities to purchase surplus electricity generated by PV systems (below 10 kW) at a price twice as much as that of the standard electricity price in November 2009, the market demand for residential PV systems has been continuously increasing.

3.4.1. *Program to purchase surplus PV power*

Based on the “Act on the Promotion of the Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers” legislated in July 2009, METI has been implementing the program to purchase surplus PV power since November 2009. Electricity generated from PV systems with the capacity of below 500 kW is eligible for the purchase and the term is for 10 years. Purchase prices under this program in fiscal year 2010(FY 2010) has not changed from the previous year and are 48 JPY/kWh (almost double of retail electricity charge for households) for residential PV systems with the capacity of below 10 kW. In case of the combination of PV system with a capacity below 10 kW and other power generation facilities, purchase price is 39 JPY/kWh. For non-residential PV systems and PV systems with a capacity of 10 kW or more without other power generation facilities and with combination of them, the purchase prices are 24 JPY/kWh and 20 JPY/kWh respectively. These prices are reviewed annually. All the users of electricity will evenly share the purchase costs.

In FY 2010, 494 projects were selected including continued projects. Among them, 401 new PV system projects were selected with total capacity of approximately 22,300 kW. Between FY 1997 and FY 2010, almost 1800 projects were newly selected.

Among them, approximately 1200 PV projects were selected with the total capacity of around 90 MW. In terms of system capacity, small systems with capacity of less than 50 kW were majority; projects smaller than 20 kW occupied almost 45% and projects bigger than 20 kW and smaller than 50 kW occupied approximately 20%. Next come the middle-sized systems, in between 50 and 1000 kW, which had around 35% share. Some system projects larger than 1 MW were conducted by utilities or enterprises. While these PV systems were mainly installed at office buildings and factories under the project, installation of PV systems at collective housings including all-electrified condominiums is increasing. Distribution centers and social welfare facilities are also included in the installation projects.

3.4.2. *Highlights and prospects*

The new program to purchase surplus PV power and subsidies for residential PV systems as driving forces, the year 2010 for Japan was a year to step forward for accomplishing 1 GW/year market.

The Japanese government formulated New Growth Strategy, Industrial Structure Vision 2010, and Basic Energy Plan and announced its policy to strategically strengthen dissemination of renewable energy as a high priority issue for Japanese economy and domestic energy supply. Based on this policy, the Ministry of Economy, Trade and Industry (METI) have drawn up the draft of detailed design for the legislation of the new Feed-in Tariff

Table 15
The cumulative installed PV power in 4 sub-markets in Japan [49].

Submarket	1992	1993	1994	1995	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Off-grid domestic	150	200	250	300	350	400	450	500	550	600	955	1101	1136	1148	1212	1884	1923	2635	3374
Off-grid non-domestic	15,260	19,170	23,260	29,360	35,890	44,900	52,300	56,200	63,000	66,227	71,692	77,792	83,109	85,909	87,376	88,266	88,886	91,998	95420
Grid connected distributed	1220	2300	5130	10,820	20,500	43,100	77,750	149,000	263,770	383,086	561,295	777,830	1,044,846	1,331,951	1,617,011	1,823,244	2,044,080	2,521,792	3,496,017
Grid connected centralized	2370	2600	2600	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	2900	5500	9300	10,740	23,333
Total (MWp)	19,000	24,270	31240	43,380	59,640	91,300	133,400	208,600	330,220	452,813	636,842	859,623	1,131,991	1,421,908	1,708,499	1,918,894	2,144,189	2,627,165	3,618,144

Table 16
Public budget for R&D demonstration/field test program and market incentive in Japan.

	FY 2008			FY 2009			FY 2010		
	R&D	Demo/field test	Market stimulation	R&D	Demo/field test	Market stimulation	R&D	Demo/field test	Market stimulation
National (BJPY)	3.7	12.17	10.7	4.16	2.35	43.05	5.98	2.38	55.13

program to achieve full-scale dissemination of PV and other renewable energy. This will set a course for dissemination of renewable energy in Japan, leading to a breakthrough to achieve PV system introduction target. Increased number of other ministries and agencies such as Ministry of Education, Culture, Sports, Science and Technology (MEXT) Ministry of the Environment (MoE) Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF) also introduced PV systems in their measures. More and more local governments started providing their own support programs for the introduction of PV systems, in response to the subsidy program for residential PV systems by the national government. In addition to introducing to public facilities, new movement for dissemination of PV system led by the local governments emerged; some started subsidizing installation to industrial facilities, others started introduction of MW-scale PV power plants. As a driving force of PV system introduction, electric utilities planed MW-scale PV power plants and started construction. As much as 100 MW of the PV plants are scheduled to be operational by 2012.

In the PV industry, 2010 marked a series of strong momentum to enhance PV business development and new entry thanks to global demand expansion and the booming domestic PV markets especially the residential, although suffered severe appreciation of the yen and global competition with emerging overseas companies. Japan Photovoltaic Energy Association (JPEA) announced its new vision towards 2030, JPEA PV OUTLOOK 2030—aiming to be the 100 Billion USD Industry, against the background of the rapidly growing global PV market today. The new vision expected the global PV market to grow by 20% until 2020, then by 13% until 2030 [50]. The vision presented a powerful stance of the Japanese PV industry, showing that the future image of the Japanese PV industry will be to establish Japanese brand, to promote global business development, and to maintain international competitiveness.

3.5. France

Globally, France stands at the fifth place for the production of PV electric energy producer [17]. According to statistics drawn up in 2009 by the “Syndicat des Energies Renouvelables (SER)”, [France's professional association of bodies involved in renewable energies], 250 MW of generating capacity were added during the year. This brings France's total installed photovoltaic capacity up to 430 MW [21]. France's photovoltaic market grew from the world's 12th largest in terms of market size to 7th largest by the end of 2009. This was due to growth that was sustained by high feed-in tariffs and a drop in the price of equipment. The broad guidelines which followed on from the legislation that emerged from the “Grenelle of the Environment” are influencing the ways in which the market is to grow over the next few years:

- A target of 1100 MW of photovoltaic installed capacity by 2012, reaching 5 400 MW by 2020.
- Confirmation that tariff incentives will remain in place until 2012 and creation of an additional tariff for photovoltaic installations in large-sized buildings, such as commercial premises and industrial warehouses. This tariff has been fixed at 0.45 EUR per kWh; however, adjustment measures were announced at the end of 2009 to reduce a speculative approach that could ultimately lead to a hardening of access conditions to the higher tariffs.
- The issuing of an invitation to tender for the construction of at least one photovoltaic power plant per region in France by 2011, providing a total of 300 MW of power.

With regard to employment, the SER represented that the number of jobs in component manufacturing and system installation that were directly generated by the sector stood at 8500. This is a dramatic increase on that year (approximately 4500).

3.5.1. Outlook

Targets set by the Grenelle of Environment include 5400 MW of photovoltaic installed capacity by 2020, capable of providing for 1% of the country's total electricity requirements. The year 2009 brought with it a number of solutions that have moved the country a great deal closer to meeting these goals.

Although—from an energy perspective—the contribution of solar power in the horizon 2020 still seems marginal, from a manufacturing perspective, the sector has the capacity to create numerous jobs all the way along the value chain, from the production of silicon to the installation of photovoltaic systems.

3.5.2. Feed-in tariffs (FIT)

FIT is one of the main measures adopted for PV in France. This mechanism has been issued in July 2006. It involves the obligation on the part of a utility to purchase electricity generated by renewable energy producers in its service area paying a tariff determined by Public authorities and guaranteed for a specific time period. A FIT's value represents the full price received by an independent producer for any kWh of electric energy produced by a RES-based system, including a premium above or additional to the market price, but excluding tax rebates or other production subsidies paid by the government [17]. FITs have been the primary mechanism used for supporting RES development in both Europe and the USA. At present, they are being applied in 20 EU member countries.

3.5.3. Incentive

There are some other additional supports. For instance, green loans and tax incentives are beneficial in credit terms. For PV systems smaller than 3 kWp the government grants a tax credit of 50% on material costs at the main residence, (maximum €8000 for singles and €16,000 for couples, valid until the end of 2012). For PV systems larger than 3 kWp, tax credit is not cumulative with FIT. Other financial incentives are a reduced VAT of 5.5% (if the equipped host building is more than two years old) and accelerated investment depreciation for companies [17].

During the course of 2009, 220 MW were installed in mainland France and a further 30 MW across its overseas territories, making for a total of 250 MW. Fig. 10 shows how installed power has grown since 2003 and Fig. 11 shows how total installed photovoltaic capacity has grown during the same period.

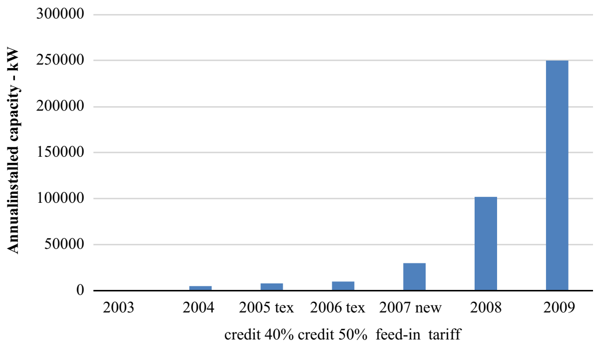


Fig. 10. PV power installed annually in France, 2003–2009 [21].

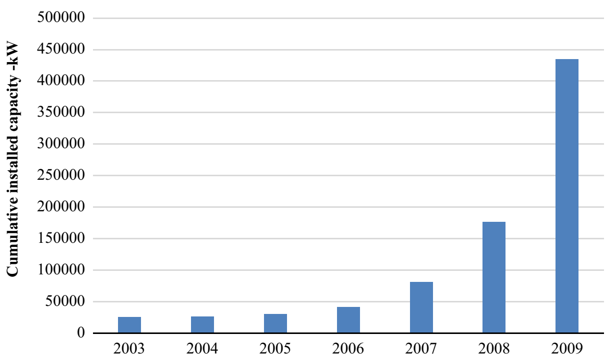


Fig. 11. Growth of the cumulative installed capacity in France (2003–2009) [21].

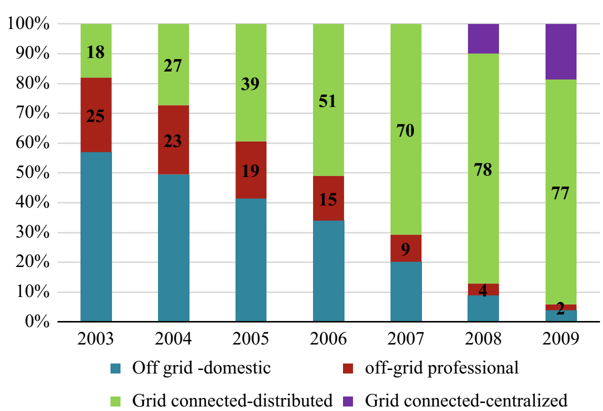


Fig. 12. Change in types of installations in France, 2003–2009 [21].

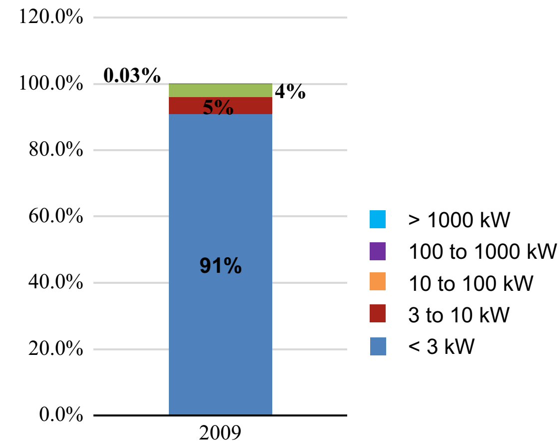


Fig. 13. December 2009 distribution of installations according to grid-connected power in France [21].

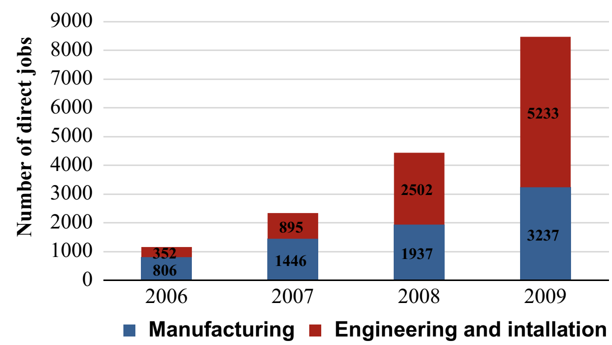


Fig. 14. Increase in the number of direct jobs (production-installation) in the PV sector in France, 2006–2009 [21].

In "grid-connected" applications, the residential market continues to drive the growth of photovoltaic electricity production in France, aided by financing schemes and very attractive tariffs. The most common applications are roof-mounted systems for individual houses (approximately 3 kW). This market is contributing to the spread of small installation companies throughout the country (Figs. 12 and 13).

The market involving larger-sized roofs (several tens of kilowatts) for commercial or business buildings is growing. The roofs of large farm buildings are particularly sought after. These applications are increasing in number at the initiative of both individual people and professional associations (Fig. 14).

3.5.4. Generating capacity

According to the Enerplan Association, the total photovoltaic power capacity installed in France has now reached 430 MW. In view of the discrepancies between the total capacity installed and the power connected to the national grid (due to delays in handling connection requests), the total photovoltaic power capacity connected up to the French grid was 269 MW as of the end of 2009, with an annual production estimation of 290 GWh. The residential market continues to grow (+225% compared with 2008), driven by incentives such as feed-in tariffs and fiscal measures. Nearly 40% of the total capacity installed in mainland France in 2009 involves large-scale roof-mounted modules; these include large surface-area farm buildings, which are particularly sought after. Growth in the numbers of ground-based power plants which began over the two previous years continued into 2009 with a number of projects, totaling some 60 MW of installed capacity. There is a significant time-lag between projects being launched and their actual implementation. This can be attributed to technical development time and to administrative procedures being longer than for other segments of the market. The "off-grid" installation market—the original basis for the photovoltaic market in France—has shrunk considerably. Total installed power capacity in 2009 was approximately 200 kW.

3.6. Germany

Germany is the world market leader for solar PV systems installation with an estimated cumulative installed capacity of 3.8 GW by the end of 2007 [17]. Within the framework of the EU Energy and Climate Directive of 2010, Germany is committed to deploying PV equipment with total capacity of 51 GW by 2020. In view of the momentum PV is now enjoying in Germany, some experts even predict that a capacity of around 60 GW will be reached [51]. The federal ministry for the environment, nature

conservation and nuclear (BMU) states about 14% of German electricity was generated from renewable sources by the end of 2007. Budgets for PV in 2010 by R&D budget for PV projects by BMU 39.0 Million €, and R&D budget for PV projects around 25.0 Million € [52]. However, solar PV has still a very small share of about 4% of total electricity generated from renewable sources. Other technologies have taken place on top of it with their share from wind around 45%, bio-energy around 27%, and hydropower around 24%. Out of all solar PV systems installed in Germany so far, about 99% are connected to the grids and only 1% is of off grid type.

Since 2004, Germany is among the countries with the highest annual PV installations worldwide. In 2010 more than 50% of the worldwide PV installations were carried out in Germany [52]. In August 2010, the German National Renewable Energy Action Plan was published. The action plan outlines that the binding domestic target of an 18% share of renewable energies in gross domestic energy consumption will be reached by 2020 and may even be surpassed and amount to 19.6% [53]. At the end of 2010, PV capacity of around 17.2 GW was connected to the grid; meaning an increase of around 7.4 GW in 2010 alone (Tables 17–19). For PV, the feed-in tariff depends on the system size and whether the system is ground mounted or attached to a building. Since 2009, there is also a tariff for self-consumed power. The rates are guaranteed for an operation period of 20 years

For 2009 the market was defined to be between 1000 MW and 1500 MW—which had significantly exceeded as the market reached 3800 MW. For 2010 to 2012, a new corridor between 2500 and 3500 MW was defined. Furthermore, for 2010 two additional reduction steps were agreed to adapt the tariff to the system price level. This resulted in an overall reduction of roughly 1/3 from end of 2009 to early 2011.With around 7 000 MW installed in 2010 the new corridor was surpassed again considerably. Therefore, it is foreseen to implement the reduction foreseen for 2012 already partly in July 2011.

Table 17
Installed PV in Germany by different institution [52].

Institution	Newly installed PV-capacity (MW)	Total installed capacity (MW)
GFNA	7.4	17.3
AGEE-Stat	7.406	17.32
BSW	7.4	17.2
GTI	7.4	17.3

Table 18
PV power installed during calendar year 2010 in 2 sub-markets in Germany [52].

Sub-market/ application	Off-Grid domestic	Off-Grid non-domestic	Grid connected distributed	Grid connected centralized	Total
PV power installed in 2009 (kW)	5	–	7406	–	7411

Since the beginning of 2009 the owners of new PV systems are legally obliged to register their systems at the German Federal Network Agency. The published statistics of the Federal Network Agency in March 2011 show an additional capacity of 7.4 GW and around 17.3 GW in total connected to the German grid.

As a consequence, Germany produced 12 TWh PV-electricity in 2010, which are roughly 2% of the domestic consumption [54] (Fig. 15). All renewable energies together have a share of 16.8% of the domestic energy supply [54]. At the same time, the German National Renewable Energy Action Plan includes a target of a 38.6% share of renewable energies in the electricity sector for 2020. For PV, the scenario assumes a future development of annually 3500 MW from 2012 to 2020. This leads to an installed capacity of almost 52 GW in 2020 and a resulting electricity production of around 7% of the overall production [55,56]. In addition to the market of grid connected systems, there is a steady request for standalone systems. It can be estimated that in 2010 around 5 MW were installed additionally in numerous applications, such as the traffic signals, garden lights, etc. Over the last years, not only the German PV market but also the German PV industry showed a strong and steady growth. The German foreign trade and inward investment agency "Germany Trade & Invest" [57] lists 69 companies involved in PV production creating a turnover of 12.2 billion € in 2010 (Fig. 16). In addition around 100 PV equipment manufacturers supply tools for every step of the PV value chain. Beside this, the development of inverter industry with a production equivalent of 11 GW is another success story. The investment in PV installations amounts to 19.5 billion € [58].

3.7. USA

In 2008 solar energy deployment increased at a record pace in the United States and throughout the world, according to industry reports. The Solar Energy Industries Association's, "2008 U.S. solar Industry Year in Review", found that U.S. solar energy capacity increased by 17% in 2007, reaching the total equivalent of 8775 MW (MW) [17].

Installed PV power: The United States (U.S.) added approximately 918 MW of PV generating capacity in 2010, bringing cumulative installed capacity to 2.5 GW (Tables 21 and 22). This represents a 56% growth in cumulative capacity over 2009. More than 50,000 PV systems were connected in 2010, compared to

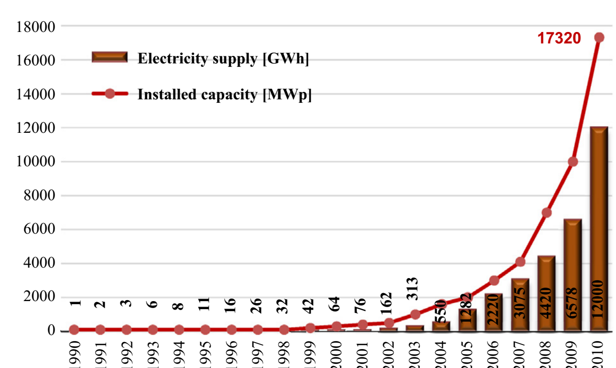


Fig. 15. Installed capacity and energy supply from photovoltaic installation in Germany.

Table 19
The cumulative installed PV in 2 sub-markets in Germany [52].

Submarket	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Off-grid domestic	14	16	20	23	26	29	32	35	40	45	50
Grid connected distributed	76	186	296	435	1105	2056	2899	4170	6120	9914	17,320
Total	90	202	316	458	1131	2085	2931	4205	6160	9959	17,370

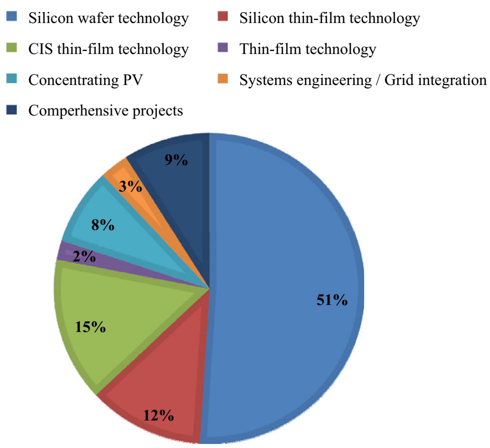


Fig. 16. Breakdown of newly approved PV funding in Germany.

34,000 in 2009, for a 47% growth in the number of grid connected systems installed annually. At the state level, California represents 32% of new capacity in 2010 compared to 49% in 2009, indicating stronger growth in other states [59]. By the end of 2010, there were approximately 152,000 distributed, grid-connected solar electric systems installed in the United States, with the United States adding 242 MW of utility-scale generation capacity that year alone. The U.S. Department of Energy (DOE) allocated a research, development, and deployment (RD&D) budget of 172.4 million USD in fiscal year (FY) 2010 (October 2009 to September 2010). These funds financed RD&D activities in partnership with national laboratories, universities, private industry, sub-national governments, and non-governmental organizations. For Solar Energy Technologies Program (SETP) R&D funding, industry partners are required to provide 20–50% matching cost share and university partners a 0–20% matching cost share.

At the federal level, a personal income tax credit is provided, while state and municipal authorities employ various solar photovoltaic-targeted tax incentives in the form of tax exemptions, tax deductions, and tax credits [60]. The U.S. Department of Treasury dispersed 544 million USD in grants in lieu of the Investment Tax Credit under Section 1603. The Department of Treasury also awarded 2.3 Billion USD in tax credits for qualified investments in advanced energy projects to support new, expanded, or re-equipped domestic manufacturing facilities, of which 1016 million USD went toward PV projects. Under the Loan Program Office, the DOE made 2099 in conditional loan guarantees for PV projects. Growth in the United States' PV market has been propelled by grid-connected PV installations, with approximately 878 MW_{DC} of new grid-connected PV capacity added in 2010. With this increase in annual capacity, the market share of grid-connected systems, in terms of cumulative installed capacity, increased from 76% in 2009 to 83% in 2010. Of the 2.5 GW of cumulative installed PV capacity at the end 2010, an estimated 2.1 GW are grid-connected, while 440_{DC} MW are off-grid.

3.7.1. Grid-connected PV

A defining characteristic of distributed PV systems is that they typically include an inverter that permits the PV system to first serve the building's load and then to send excess power to the utility grid. By the end of 2010, there were more than 152,882 distributed PV systems interconnected across the United States. Centralized PV systems (utility applications) generate electricity that is fed directly to the grid, without serving an on-site load. This sector expanded from 66 MW_{DC} installed in 2009 to approximately 242 MW_{DC} installed in 2010. The largest utility-scale PV plant in the United States is the Copper Mountain facility in Nevada, with 55 MW_{DC} of capacity.

3.7.2. Off-grid PV

There was approximately 40 MW_{DC} of additional off-grid capacity added in 2010. Table 20 displays annual installed PV capacity for 2010 across four sub-markets. Annual installed PV capacity totals 918,000 kW in 2010, with grid-connected capacity of 878,000 kW and off-grid capacity of 40,000 kW. For off-grid installations, domestic and non-domestic segmented data is unavailable for 2010.

3.7.3. Market drivers

In 2010, the solar PV installations in the United States grew by 97% compared to 2009, for a total of approximately 918 MW MW_{DC} installed this year. Two of the major federal policy drivers for growth in PV installations include the 30% investment tax credit (ITC) and the five-year accelerated depreciation (modified accelerated cost recovery schedule or MARCS). The ITC applies to both residential and commercial installations and the MARCS apply only to commercial installations. Under an amendment to MARCS, eligible PV property placed in service after 8 September 2010, and before 1 January 2012, qualifies for 100% first-year bonus depreciation. For 2012, bonus depreciation is still available, but the allowable deduction reverts from 100% to 50% of the eligible basis. DOE accelerates the research, development, and deployment of all solar energy technologies through its Solar Energy Technologies Program (SETP). In 2010, SETP held workshops with industry and other stakeholders to develop a roadmap to reach the goal of 1 USD per watt installed price of utility-scale PV systems by 2020.

By 2020, to demonstrate the commercial viability of the 75% reduction approach for

PV

- Utility (100 MW)-1 USD/W
- Commercial (200 kW)-1.25 USD/W
- Residential (5 kW)-1/50 USD/W

CSP-Utility-3.50 USD/w, including 16 h storage

3.7.4. Target

Millions of Americans are enjoying the benefits of owning a solar hot water system or solar–electric. There were 83000 solar–thermal

Table 20
2010 figures for PV power installed in 4 U.S. sub-markets.

Sub-market/ application	Off-grid domestic and non-domestic	Grid-connected distributed	Grid-connected centralized	Total
PV power installed in 2010 (kW)	40,000	636,000	242,000	918,000

Table 21
PV power and the broader national energy market in U.S.

Total national (or regional) PV capacity as a % of total national (or regional) electricity generation capacity	New (2009) PV capacity as a % of new electricity generation capacity (2009)	Total PV energy production as a % of total electricity consumption
0.003	0.05	0.06

Table 22
The cumulative installed PV power in four sub-markets in USA.

Submarket	1995	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Off-grid domestic	19.3	23.3	27.5	32	37.5	43.5	50.5	58.9	68.9	88	100	114	134	154	400	400
Off-grid non-domestic	25.8	30.2	35	40.2	46.7	55.2	64.7	77.7	93.7	112	133	15	191	216		
Grid connected distributed	9.7	11	13.7	15.9	21.9	28.1	40.6	63.6	95.6	154	219	322	465	735	–	1737
Grid connected centralized	12	12	12	12	12	12	12	12	18	22	27	32	40.5	63.5	130	372
Total (GW)	66.8	76.5	88.2	100.1	117.3	138.8	167.8	212.2	275.2	376	479	483	830.5	1168.5	1633	2549

and solar–electric systems installed around the U.S. in 2007 [61]. Although state solar programs have played a key role in driving this growth, the 30% federal ITC has been the most important component. In recent report on the economic impact of the ITC, 8-year extension of the residential and business credits could result in over 6000 MW of annual solar PV and solar thermal installations by 2016 [17]. If Congress had failed to extend the ITC in 2008, Navigant projected that annual installations would have fallen to about 1500 MW by 2016.

4. Conclusion

The development of renewable energy has become necessary, and with GHG emission being a major concern to combating global warming, solar, with its zero-emission zero-noise global-reach properties should be paid more attention. A noticeable present trend in renewable energy is the move from decentralized applications to centralized. Seven nations lead in successful increase of PV-generated electricity. For considerable market and user growth, retail financing terms need to be flexible. The leading nations set renewable portfolio standards and Feed-in tariffs and give out incentives, subsidies, and tax exemptions. Their active promotion of Building Integrated Photovoltaic (BIPV) also factors significantly in their increase of PV-generated energy.

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